Supporting Information

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Ultrawide Angle, Directional Spectrum Splitting with Visible-Frequency Versatile Metasurfaces

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**EXPERIMENTAL METHODS**

**Metasurface Fabrication.** For the double-trapezoidal metasurface samples described here the substrate used was polished Si that was covered first with 100 nm of Ag followed by a 40 nm SiO₂ spacer using electron-beam evaporation. The patterned trapezoidal designs were then exposed in Bi-layer PMMA using a JEOL 9300 100kV electron-beam lithography system. The fabricated sample contains 10 identical nanostructured arrays with individual size of 200×200 µm², uniformly placed in a 5×2 matrix with total area of 1800×600 µm². To ensure highest resolution patterns development was completed using cold development at 5°C with a solution of 7:3 IPA: H₂O ratio for 1min. The final layer, 40nm of Ag covered were deposited with electron-beam evaporation and lifted off in 1165 Microchem resist remover at 50°C.

**Angular Measurement.** Experimental characterization of samples was completed by collection of reflection spectra using an angle resolved reflection system. A broadband halogen lamp was coupled into an optical fiber. Proper collimation of the light was found to be important in
producing the sharpest reflection features for the desired wavelengths due to the design’s high sensitivity to the incident angle. Thus, prior to reaching the sample, the light from the fiber was focused, collimated and polarized using a series of achromatic doublet lenses and a linear polarizer in the light pathway, which was helpful at normal incidence for all measurements. After focusing the 4X Nikon achromatic collection objective, the motorized rotation stage position is manually adjusted to the eccentric point to eliminate image shift during data collection at multiple angles. The reflection is then coupled into a spectrometer consisting of a 303-mm-focal-length monochromator and Andor Newton electron multiplication charge-coupled device (EM-CCD) for a series of measurements scanning different reflection angles.

THEORETICAL CALCULATIONS

Full-field electromagnetic wave calculations were performed using Lumerical™, a commercially available finite-difference time-domain (FDTD) simulation software package. 3D simulations for were performed for the proposed metasurface design with a unit cell area of 450×1000 nm\(^2\) at \(x-y\) plane using periodic boundary conditions. Perfectly matched layers (PML) conditions are utilized along the propagation of electromagnetic waves (\(z\)-axis). Plane waves were normally incident to the nanostructures along the \(+z\) direction, and reflection and transmission is collected with power monitors placed behind the radiation source and after the structure, respectively. The reflected powers at a full range of angles are calculated by the far-field calculation option of the reflection power monitor. Electric and magnetic field distributions are detected by 2D field profile monitors in \(x-z\) plane. The complex refractive index of Ag for simulation is utilized from the data of Palik (0-2 \(\mu\)m)\(^1\) and SiO\(_2\) is from the data of Palik\(^1\).
Angle-dependent spectral measurement at far field for fixed wavelength

In terms of light power of diffracted beam at far field, Figure 3e and 3h plot the simulated power distributions at fixed wavelengths of green light and red light, respectively. It is observed that there is very little power at other diffraction peaks and the power contrast from the major diffraction peak to others is at least higher than 15 folds.

The measured far field power as a function of angles for single wavelength could be retrieved from Figure 4b and 4c and additional spectral measurements for other angles, as shown in Figure S1. The angular measurements at lower angles below 30° are restricted by the physical limitations of the setup as the collection lens start to block incoming light. The experimental measurement reconfirms that majority of the reflection light could be redirected to the fundamental first order diffraction mode to either side, and very few power is located at other angles or other diffraction modes.
Figure S1. a, Measured reflection power distribution as a function of angles at far field for fixed wavelength of green light (560 nm) and b, red light (810 nm).

Reference